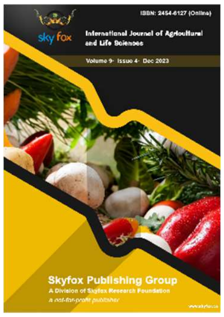

International Journal of Agricultural and Life

ISSN: 2454-6127(Online) Journal homepage: http://www.skyfox.co

A Comprehensive Review of Different Nano – Biocomposite Materials Used in The Food Packaging Industry

George R. Moore*

To cite this article : George R, M. (2023). A Comprehensive Review of Different Nano – Biocomposite Materials Used in The Food Packaging Industry. Int J Agric Life Sci, 9(4), 418-422. doi: 10.22573/spg.ijals.023.s122000117

To link to this article : https://doi.org/10.22573/spg.ijals.023.s122000117

Data Availability Statement : All relevant data are within the paper and its Supporting Information files.

Funding : The author(s) received no specific funding for this work.

Competing Interests : The authors have declared that no competing interests exist.

International Journal of Agricultural and Life Sciences- IJALS (2023), Volume 9 (4) pp.418-422
http://dx.doi.org/10.22573/spg.ijals.023.s122000117
Available online at http://www.skyfox.co
ISSN: 2454-6127

REVIEW ARTICLE

A Comprehensive Review of Different Nano – Biocomposite Materials Used in The Food Packaging Industry

George R. Moore*

* Department of Food and Nutrition Security, Stellenbosch University, Stellenbosch, South Africa
*Author to whom correspondence should be addressed; E-Mail: moorer@gmail.com
Received: 18 Sep 2023/ Revised: 15 Oct 2023/ Accepted: 20 Nov 2023/ Published: 31 Dec 2023

Abstract: Nanotechnology is the ability to manipulate materials at the nanoscale, which is approximately 1300nm in size. At this scale, particles have a significantly large surface area and display unique characteristics, including electronic, optical, and catalytic properties. As a valuable tool, nanotechnology has been employed in the food industry to enhance production processes and improve food quality. It is estimated that by 2023, approximately 1400 food and agricultural companies will actively engage in research related to nanotechnology. The impact of nanotechnology on the food industry is far-reaching and encompasses various aspects such as food processing, product formulations, food safety and biosecurity. One notable advancement is in the development of intelligent, active, and smart food packaging systems. With nanotechnology, food packaging can now possess sophisticated features that help monitor freshness levels, control microbial growth, and provide other benefits that extend shelf life. This revolutionizes conventional packaging methods by promoting optimal preservation of products while maintaining high standards of safety for consumers. In conclusion, nanotechnology continues to transform the way we produce and consume food through its innovative applications in the industry. Its potential for improving efficiency and enhancing food quality makes it an essential component for future advancements in the field of agriculture and nutrition.
Keywords: Nanomaterials, nanocapsule, nanoemulsion, liposomal nanovesicle, nanotube, nanoceramic, nano clay, nanowire.

INTRODUCTION

The current market value of nano enabled food and beverage packaging in 2008 was $4.21 bn and is forecasted to grow to $7.3 bn by 2014 (Blasco and Pico, 2011). The largest part of the market was active package followed by intelligent package. Polymers nanotechnology has the potential to provide nanomaterials for food packaging. About 42% of polymer global market are used for packaging systems (Silvestre et al., 2011). Faced with challenges of lack of biodegradability of food packaging materials, new biopolymers are currently being developed. Within a short while, biopolymers were observed to lack the mechanical properties and high cost compared to synthetic counterparts. Some of the disadvantages that have been associated with conventional packaging materials can be overcome using nanotechnology. The use of nanotechnology for improvement of biopolymers is a promising endeavor (De Azeredo, 2009). Numerous studies have shown that biopolymer nanocomposites exhibited great and novel properties. This has resulted into development of biopolymer nanocomposites with improved functionalities including thermal, mechanical, and barrier properties (Bott et al., 2014). In fact, incorporating nanomaterials (such as nano clays and other polymer matrix nanocomposites) into packaging materials will tremendously improve their functionalities to protect food and enhance the shelf life of packed food (De Azeredo, 2009). There are numbers of commercial nanomaterials available for food packaging. These materials contain nanoparticles that will be discussed in this chapter. The type, mechanism, and properties of the nanoparticles will also be reviewed. Lastly, the status and safety concerns of nanomaterials in food packaging will be discussed.

TYPES AND APPLICATIONS OF NANOPARTICLES USED IN FOOD PACKAGING

Nanoparticles can be categorized into different groups depending on the features being considered. Dimensionally, there are three distinguished types of nanoparticles. Iso dimensional, nanotubes or whiskers, and polymer layered crystal, respectively, with three, two, and one nanometric dimension(s) (Bott et al., 2014). Another category, based on the role of nanoparticles in food packaging systems, is nano reinforcement, active and smart/intelligent nano packaging.

NANO REINFORCEMENT

Nano reinforcements of biopolymer for food packaging systems have been achieved by using nanosized fillers. Nanoparticles are high in surface area, and therefore, favor the filler matrix interaction and overall performance of the food packaging system(De Azeredo, 2009). Most

International Journal of Agricultural and Life Sciences- IJALS (2023), Volume 9 (4) pp.418-422
http://dx.doi.org/10.22573/spg.ijals.023.s122000117
Available online at http://www.skyfox.co
ISSN: 2454-6127

biodegradable polymers suffer from mechanical properties and are too weak for practical use (Bordes et al., 2009). Hence, numerous efforts have been made to improve the polymer properties (stiffness, permeability, thermal stability, and crystallinity) through the inclusion of nanosized fillers (Bordes et al., 2009). Nano fillers can be layered (e.g., clays), spherical (e.g., silica), or acicular (e. g., cellulose whiskers, carbon nanotubes) (Bordes et al., 2009). Recent studies have shown that the development of food packaging materials that include nanoclay and silicate increased water vapor barrier with reduced impact on tensile property. Also, effect of barrier properties of nanocomposite materials depends on the type of nanoclay (Bordes et al., 2009; Rhim et al., 2009).

Nano polymer composites are currently being used in food packaging due to their light weight and their ability for keeping food fresh during storage, secured during transportation, and safe from microbes (Amenta et al., 2015). Layered inorganic solids like clays and silicates are the most used for nano reinforcement due to availability, low cost, relatively simple processing, and significant mechanical enhancements. Layered silicates are two dimensional layered with 1 nm thickness and are several micros long. Inclusion of clays in polymer matrix results in creation of twisting path, thus preventing inflow of light, water, and oxygen (Bott et al., 2014). The barrier properties of clays nanocomposites have been stated to be due to their internal structures that are in two forms including intercalated (polymer penetration resulting in ordered multilayer structure with polymer/inorganic layer at nanometer separation) and exfoliated (extensive polymer penetration resulting in clay layer delaminated and randomly dispersed in polymer matrix) (Bott et al., 2014).

ACTIVE PACKAGING

Incorporation of metal/metal oxide nanoparticles into materials for food packaging system offers antimicrobial protection of food surfaces and thus keeps food fresher over time (Blasco and Pico, 2011). Active packages are not inert since they interact with the food content. They are either absorbing or releasing agents/systems to maintain quality of food (Pereira de Abreu et al., 2012). The interaction with food and its environment includes oxygen scavengers, ethylene removers, and carbon dioxide regulator (Silvestre et al., 2011).

The most commonly used nanoparticles for antimicrobial effect is silver, while copper, zinc, and titanium nanoparticles have received lesser attention. Silver and zinc nanoparticles offer antimicrobial activities, titanium offers photoprotection against UV, and copper acts as humidity sensing (Llorens et al., 2012). Inclusion of nanoparticles in polymer matrix has shown antimicrobial activities against some foodborne pathogens such as Listeria monocytogenes, Salmonella typhimurium, Escherichia coli, Staphylococcus. aureus, Candida albicans, etc. Silver nanoparticles (110nm) exhibit higher antimicrobial activities compared to larger sizes particles. Food contact material containing TiO_2 showed increase in antimicrobial effect when exposed to UV irradiation (Llorens et al., 2012).

However, the mechanisms of antimicrobial activity of the metal/metal oxide nanoparticles are still controversial (Llorens et al., 2012). Among the proposed mechanisms of silver nanoparticles are (i) cell surface attachment, lipopolysaccharides degradation, and cell membranes disruption; (ii) cell absorption of silver particle that results into DNA damage; and (iii) disruption of cell biochemistry when silver ion reacts with biochemical molecules containing sulfur, oxygen, and nitrogen (Silvestre et al., 2011). As for TiO_2, UV activation damages cell membrane leading to peroxidation of the polyunsaturated phospholipids and fatty acid of microbial cell membranes (Silvestre et al., 2011).

Active nanomaterials have also been investigated to control oxygen that causes browning, microbial spoilage, rancidity, etc. and ethylene responsible for ripening. Also, TiO_2 nanoparticles have shown the potential to act as oxygen scavengers and silver nanoparticles exhibit absorption and decomposition of ethylene (Silvestre et al., 2011).

SMART AND INTELLIGENT PACKAGING

Smart or intelligent packaging system involves the ability of food packages to monitor the food conditions and its surrounding, and thus, acts as biosensors (Amenta et al., 2015). Intelligent packaging acts as time temperature indicator, gas detectors, and freshness and/or ripening indicators (Pereira de Abreu et al., 2012). This technology allows for visible determination of the quality of packaged food. Nano sensors which respond to change in environment—are currently being incorporated into food packaging to indicate the environmental conditions that the food has been exposed to. Also, nano sensors are capable of detecting the presence of certain chemical compounds, pathogens, and toxins (Silvestre et al., 2011).

For instance, the deleterious role of oxygen during storage has been well documented as oxygen supports growth of microbes aerobically. Early detection of oxygen in packaged food products is essential towards knowing the storability of such products. Nanoparticles have now been embedded into packaging materials for the purpose of early and easy detection of oxygen molecules. In the presence of oxygen and active reagent (e.g., methylene blue and/or glycerol), nanoparticles function as catalyst that aid formation of color when packaged materials are exposed to UV. Titania and Tin oxide have been reportedly used for development of photosensitive nano packaging materials for the detection of oxygen (Silvestre et al., 2011). The development or disappearance of color depends on the amount of oxygen.

ENVIRONMENT AND HEALTH SAFETY RISK OF FOOD PACKAGING NANOMATERIALS

There exist great public concerns about the adoption of nanotechnology in food packaging. The use of nanoparticles in food packaging system has led to exposure of nanoparticles that can be potentially consumed through oral uptake (Cruz et al., Also, the presence of nanomaterials in the environment raises concerns about the possible environmental problems. Nanomaterials may potentially bind to nutrients in the soil and reduce nutrient availability to plants. They can equally react with other chemicals that could become a potential toxic compound. The life cycle of nanoparticles in the environment is still not known. Presence of nanoparticles in the atmosphere raises concern to human (Silvestre et al., 2011).

International Journal of Agricultural and Life Sciences- IJALS (2023), Volume 9 (4) pp.418-422
http://dx.doi.org/10.22573/spg.ijals.023.s122000117
Available online at http://www.skyfox.co
ISSN: 2454-6127

One of the major concerns of NMs in food packaging is the possibility of migration of nanoparticles into food product that could later be ingested by people. Presence of inorganic nanostructures and carbon nanostructures in living organisms may disrupt normal activity and may lead to malfunctioning and diseases. Also, nanomaterials can easily penetrate biological membranes, travel through the blood stream, and accumulate into numerous body organs (Cushen et al., 2012). Nanomaterial can cause DNA mutation and induce structural damage to mitochondria and then cell death (Blasco and Pico, 2011). Toxicology of nanomaterials depends on size, chemical, morphology, surface structure, surface charge, solubility, aggregation, and other chemical functional groups (Blasco and Pico, 2011). The food safety authority in UK has provided the list of nanomaterials that are safe for food/food contact materials as silica, nanoclay, nanosilver, and titanium nitride (Amenta et al., 2015).

According to, numerous nanoparticles in different packaging materials have been investigated for their likelihood of being released into packaged food. There are mixed reports on safety of nanomaterials based on migration. The first opinion stated that migration of nanoparticles into food from contact packaging materials is unlikely to occur. The study made use of food models including alcohol, iso-octane, and acetic acid and showed that there was lack of detectable amount of titanium nanoparticles from plastic (low density polyethylene) films into food materials using ICPMS method, even under severe conditions. However, there is possibility that nanoparticles of <3.5 nm size might migrate to measurable level into food (Bott et al., 2014). Carbon nanotube has been reported to be toxic to human cell, most especially the skin (Silvestre et al., 2011). Graphene nanoparticles have equally been reported to exhibit toxicity against bacteria as well as the human cells (Guo and Mei, 2014).

Adoption of nanomaterials for food packaging at commercialization stage is delayed or hindered by the concerns on public health (Cruz et al., 2013). The interaction of the nanoparticles with the polymer matrix will determine the migration potential of nanoparticles from food packages. The nature of bonding system between nanoparticles and other components of packaging materials will have an effect on the number of nanoparticles that could possibly be released into packaged food. Nanoparticles could possibly be washed off the surface of packaging materials or get released through diffusion process from the interior of the packaging of material. Numerous food models have been used to determine the effect of food properties from the release of nanoparticles under different storage and processing conditions. The results revealed that migration of nanoparticles depends on the packaged food properties, exposure time, and temperature.

REGULATIONS OF NANOMATERIALS FOR FOOD PACKAGING

As a result of public concerns over the safety of the use of nanoparticles in food packaging materials, numerous authorities have come up with some regulations. Adoption of novel technology that potentially impacts human should be regulated. Therefore, a number of regulations at national level and industrial level have been formulated in order to guide the use of nanomaterials in food packaging system.It is important to note that regulation of nanomaterials for food packaging is comprehensively covered in EU regulation (Food contact materials, plastic food contact materials, active and intelligent materials, and articles with reference code (EC) 1935/2004, (EC)20/2011, and (EC) 450/2009, respectively) (Bott et al., 2014). Apart from setting guidelines on the use of nanomaterials in food packaging, the labeling and reporting schemes of nanomaterials are also covered. The EU parliament, EU member states, and NGOs have stated the need for labeling the nanomaterials used in food system and packaging. Labeling will encourage more transparency, traceability, and information with respect to the use and possible exposure of nanomaterials in food. Three EU member states (France, Belgium, and Denmark) have equally made it compulsory to report the presence of nanomaterials in products including food/food contact materials (Amenta et al., 2015).

Many other countries have also come up with regulation of nanomaterial application in food/food contact surfaces. Most of them focus on defining nanomaterials based on size and call for adequate assessment of their toxicology level. However, countries like Indonesia, Australia/New Zealand, Malaysia, China, African, and South America lack a well-designed and specific regulation on nanotechnology application in food, but have food specific legislation. Other aspects of the regulation are similar to what was stated in EU regulation. Future collaboration is required regarding exchange of information (Amenta et al., 2015).

SOURCE OF MATERIALS

The source of nanomaterials as well as their safety will be paramount in religious view of food packaging nanomaterials. Compositionally, all nanomaterials are Halal and Kosher safe except the possible occurrence of contamination and safety issues. Most especially, the use of pork gelatin might raise the Halal status of nano polymer composite.

PROTECTION AND PRESERVATION EFFICIENCY

Religious guideline of food required protection against possible entrance of uncleaned agents into food. Food packaging material should be graded based on protection efficiency. Ability to provide effective protection against physical, chemical, and biological damage should form important factor in developing religious view on food packaging systems.

HEALTH AND ENVIRONMENTAL SAFETY

Most religions, most especially Islam, cater for all living and non living things; therefore, any food packaging system should be safe. Producing, selling, distributing, and consuming of unsafe products are religiously disallowed. The use of toxic nanoparticles in food packaging should be considered unlawful. Life cycle analysis should be incorporated into religious evaluation of food packaging system.

LABELING

Transparency is an important part of many religions. Most religions view non-disclosure as unlawful and cheating. Hence, declaration of the composition should be a mandatory religious requirement for food packaging system. Food packaging system should be amicable to convey needed information to guide consumer's understanding of the food as well as the packages. Reports on migration of nanoparticles should be stated on food packaging. In order to remain competitive, adoption of nanotechnology in food production and packaging should be encouraged. The source of nanomaterials and their safety will be paramount towards recommendation of Halal and Kosher status of food packaging systems. Presently, all nanomaterials are Halal, except those that cause contamination and raise safety issues of food products.

CONCLUSION

The food industry has observed major advancements in the packaging sector with most active and intelligent innovations. These advancements have led a way towards the improved food quality and safety. This paper has overviewed the recent advances in the food packaging sector regarding the security and sustainability. This new approach has mainly focused on retarding the oxidation, regulating moisture migration, microbial growth, respiration rates and improving the overall system of food packaging sector. Various aspects of technologies, systems, standards like advanced packaging material and machinery, automation and control solutions, supply chain management, inspection system, usefulness of robotic platforms, and software application have been reviewed

REFERENCES

1. Amenta, V., Aschberger, K., Arena, M., Bouwmeester, H., Botelho Moniz, F., Brandhoff, P., Peters, R.J., 2015. Regulatory aspects of nanotechnology in the Agri/feed/food sector in EU and non EU countries. Regul. Toxicol. Pharmacol. 73 (1), 463476. https://doi.org/ 10.1016/j.yrtph.2015.06.016.
2. Blasco, C., Pico, Y., 2011. Determining nanomaterials in food. TrAC Trends Anal. Chem. 30 (1), 8499. https://doi.org/10.1016/j.trac.2010.08.010.
3. Bordes, P., Pollet, E., Averous, L., 2009. Nano biocomposites: biodegradable polyester/ nanoclay systems. Prog. Polym. Sci. 34 (2), 125155. https://doi.org/10.1016/j. progpolymsci.2008.10.002.
4. Bott, J., St€ormer, A., Franz, R., 2014. A model study into the migration potential of nanoparticles from plastics nanocomposites for food contact. Food Packag. Shelf Life 2 (2), 7380. https://doi.org/10.1016/j.fpsl.2014.08.001.
5. Bott, J., St€ormer, A., Wolz, G., Franz, R., 2012. Migration potential of nanoscale silver particles in food contact polyolefins. Paper Presented at the the 5th International Symposium on Food Packaging.
6. Cruz, R.M.S., Rubilar, J.F., Khmelinskii, I., Vieira, M.C., 2013. Nanotechnology in Food Applications. pp. 103122. https://doi.org/10.1002/9781118659083.ch3.
7. Cushen, M., Kerry, J., Morris, M., CruzRomero, M., Cummins, E., 2012. Nanotechnologies in the food industry—recent developments, risks and regulation. Trends Food Sci. Technol. 24 (1), 3046. https://doi.org/10.1016/j.tifs.2011.10.006.
8. De Azeredo, H.M., 2009. Nanocomposites for food packaging applications. Food Res. Int. 42 (9), 12401253.
9. Echegoyen, Y., Neri'n. C., 2013. Nanoparticle release from nanosilver antimicrobial food containers. Food Chem. Toxicol. 62, 1622.
10. Farhoodi, M., Mousavi, S.M., Sotudeh Gharebagh, R., EmamDjomeh, Z., Oromiehie, A., 2014. Migration of aluminum and silicon from PET/clay nanocomposite bottles into acidic food simulant. Packag. Technol. Sci. 27 (2), 161168.
11. Fortunati, E., Peltzer, M., Armentano, I., Torre, L., Jimenez, A., Kenny, J., 2012. Effects of modified cellulose nanocrystals on the barrier and migration properties of PLA nano biocomposites. Carbohydr. Polym. 90 (2), 948956.
12. Guo, X., Mei, N., 2014. Assessment of the toxic potential of graphene family nanomaterials. J. Food Drug Anal. 22 (1), 105115. https://doi.org/10.1016/j.jfda.2014.01.009.
13. Huang, Y., Chen, S., Bing, X., Gao, C., Wang, T., Yuan, B., 2011. Nanosilver migrated into foodsimulating solutions from commercially available food fresh containers. Packag. Technol. Sci. 24 (5), 291297.
14. Lin, Q.B., Li, H., Zhong, H.N., Zhao, Q., Xiao, D.H., Wang, Z.W., 2014. Migration of Ti from nanoTiO2polyethylene composite packaging into food simulants. Food Addit. Con tamin. A 31 (7), 12841290.
15. Llorens, A., Lloret, E., Picouet, P.A., Trbojevich, R., Fernandez, A., 2012. Metallic based micro and nanocomposites in food contact materials and active food packaging. Trends Food Sci. Technol. 24 (1), 1929. https://doi.org/10.1016/j.tifs.2011.10.001.
16. Norbilah, S., Manaff, A., 2012. Acceptance of Nanotechnology Among Halal Food Manufacturer. Universiti Utara Malaysia, Kuala Lumpur, Malaysia.
17. Pereira de Abreu, D., Cruz, J., Paseiro Losada, P., 2012. Active and intelligent packaging for the food industry. Food Rev. Int. 28 (2), 146187.
18. Rhim, J.W., Hong, S.I., Ha, C.S., 2009. Tensile, water vapor barrier and antimicrobial properties of PLA/nanoclay composite films. LWT Food Sci. Technol. 42 (2), 612617. https:// doi.org/10.1016/j.lwt.2008.02.015.
19. Schmidt, B., Katiyar, V., Plackett, D., Larsen, E.H., Gerds, N., Koch, C.B., Petersen, J.H., 2011. Migration of nanosized layered double hydroxide platelets from polylactide nanocomposite films. Food Addit. Contamin. A 28 (7), 956966.
20. Silvestre, C., Duraccio, D., Cimmino, S., 2011. Food packaging based on polymer nanomaterials. Prog. Polym. Sci. 36 (12), 17661782. https://doi.org/10.1016/j. progpolymsci.2011.02.003.

http://dx.doi.org/10.22573/spg.ijals.023.s122000117
Available online at http://www.skyfox.co
ISSN: 2454-6127

21. Song, H., Li, B., Lin, Q.B., Wu, H.J., Chen, Y., 2011. Migration of silver from nano silver polyethylene composite packaging into food simulants. Food Addit. Contamin. A 28 (12), 17581762.

How to cite this article
George R, M. (2023). A Comprehensive Review of Different Nano – Biocomposite Materials Used in The Food Packaging Industry. Int J Agric Life Sci, 9(4), 418-422. doi: 10.22573/spg.ijals.023.s122000117.

CONFLICTS OF INTEREST

"The authors declare no conflict of interest".